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THE CAUSES OF OBNOXIOUS TASTES AND ODORS SOMETIMES OCCURRING IN THE CLEVELAND WATER SUPPLY[1]

BY J. W. ELLMS[2] AND W. C. LAWRENCE[3]

Consumers of the Cleveland water supply have been troubled from time to time for a number of years with obnoxious tastes and odors in the water. The taste and odor complained of is described as "medicinal" or like chlorine or carbolic acid. The taste is particularly offensive in hot water or in tea made with it. The taste is not usually complained of for more than a few days at a time, indicating that the contamination is intermittent. Complaints are more frequent following ice movements in the lake, during the early spring months, than at other times, although high winds, which agitate the lake and set up unusual surface and subsurface currents, appear to be in some way related to the recurrence of these tastes.

The authors have been investigating the problem for several years and have come to the general conclusion that the taste was related in some way to trade wastes discharged into the Cuyahoga River and from thence into the lake, and that the chlorination of the water supply brought out or developed the foul taste.

The Cuyahoga River flowing through the heart of the city is lined along its banks for miles with manufacturing plants of varied character. The stream is not a large one and has a low current velocity, especially through the manufacturing district. Consequently it is hardly more than a lagoon of the lake, rising and falling with the changes in the lake level. The stream is badly polluted, receiving besides trade wastes, a large proportion of the domestic sewage of the valley district.

The two water works intakes of the city are approximately 4 miles north of the mouth of the Cuyahoga River. One intake is a submerged crib, and the other is a steel crib with superstructure. They are located within 3700 feet of each other in about 50 feet of water. Reference to the map will show the relative positions of the intakes, mouth of river, outfall sewers on lake front, and the sumerous sampling points located on the Cuyahoga River.

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SAMPLING POINTS

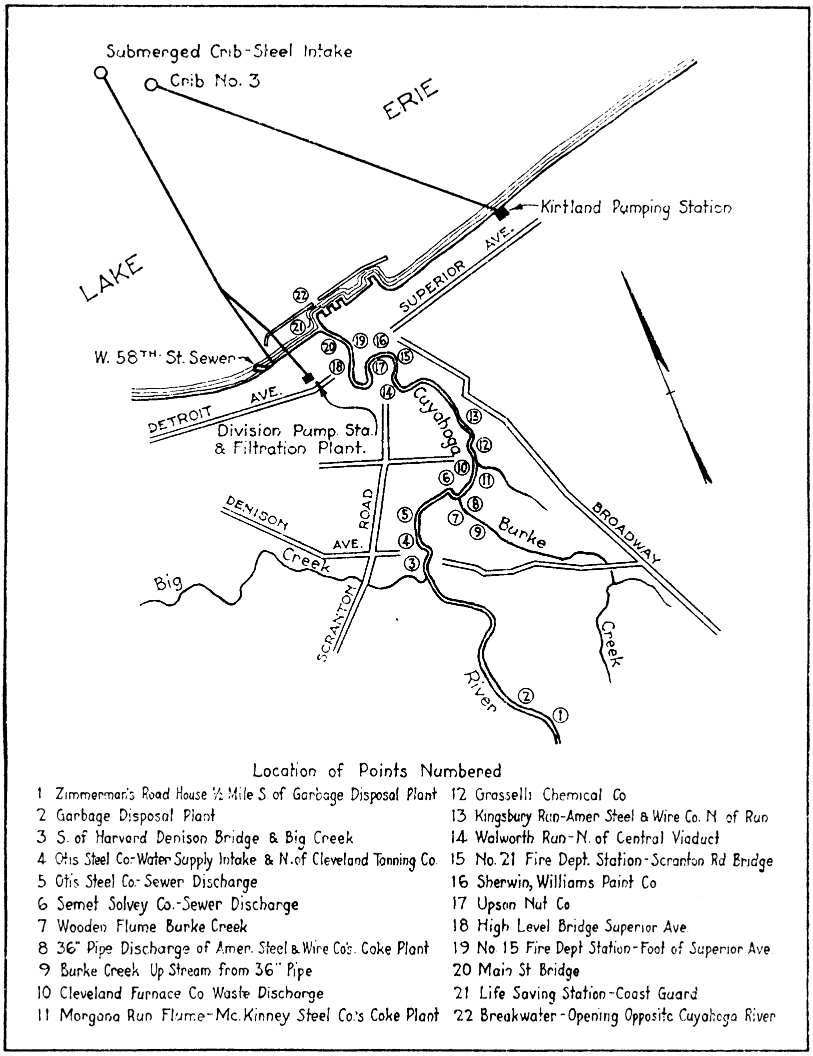
It was decided at the beginning of 1920, to sample systematically for a time (1) the water of the Cuyahoga River at selected points for a distance of several miles up the stream, (2) the sewage discharging from the West Fifty-eighth Street sewer outfall on the lake front, and (3) the lake water coming through the two water works intakes. It was hoped that, by sampling at a large number of points, the original source of the waste producing the foul taste in the lake water might be located more definitely. By elimination we succeeded in locating the sources of the wastes primarily responsible for the obnoxious tastes in the water supply.

The active sampling was carried on during the first three months of the year or prior to the breaking up of the ice in the lake. Some of the samples were collected later in the year, principally to confirm, if possible, by direct chemical tests, our earlier work.

Between January 7 and April 1, 1920, 719 sewage and river samples were collected. Of this number, 216 were taken from the mouth of the West Fifty-eighth Street sewer. This sewer collects the sewage from quite an area on the west side of the river, including a large number of industrial plants.

From the Cuyahoga River, 120 samples were taken near the mouth of the river opposite the U. S. Coast Guard Life Saving Station; 95 samples from Cleveland's Fire Station No. 21, located on the Cuyahoga River at West Third Street; 82 samples from Cleveland's Fire Station No. 15, located on Superior Avenue; and 206 samples from various sewer outfalls on both sides of the stream, and from the channel of the river. Samples of the river water were collected as far south as the Cleveland garbage disposal plant at Willow, Ohio, but the samples collected with the launch were taken only as far south as Burke Creek, a distance by river of 5.6 miles from the mouth of the stream. Burke Creek was as far as it was possible to take the launch on account of the shallow water in the river. This creek, however, receives considerable sewage from territory still further south.

Samples from the mouth of the West Fifty-eighth Street sewer, the mouth of the river opposite the Life Saving Station, and Fire Stations



Location of Points Numbered

1 Zimmerman's Road House ½ Mile S. of Garbage Disposal Plant
2 Garbage Disposal Plant
3 S. of Harvard Denison Bridge & Big Creek
4 Otis Steel Co.-Water Supply Intake & N. of Cleveland Tanning Co.
5 Otis Steel Co.-Sewer Discharge
6 Semet Solvey Co.-Sewer Discharge
7 Wooden Flume Burke Creek
8 36" Pipe Discharge of Amer. Steel & Wire Co's. Coke Plant
9 Burke Creek Up Stream from 36" Pipe
10 Cleveland Furnace Co Waste Discharge
11 Morgana Run Flume-Mc.Kinney Steel Co.'s Coke Plant
12 Grasselli Chemical Co
13 Kingsbury Run-Amer Steel & Wire Co. N of Run
14 Walworth Run-N. of Central Viaduct
15 No. 21 Fire Dept. Station-Scranton Rd Bridge
16 Sherwin, Williams Paint Co
17 Upson Nut Co
18 High Level Bridge Superior Ave.
19 No 15 Fire Dept Station-Foot of Superior Ave.
20 Main St Bridge
21 Life Saving Station-Coast Guard
22 Breakwater-Opening Opposite Cuyahoga River

FIG. 1. LOCATION OF SAMPLING POINTS

Nos. 15 and 21 were taken three times daily, at 8:00 a.m., 4:00 p.m. and 12:00 p.m. for a portion of the first three months of the year. Late in the year a large number of special samples were taken on inspection trips of practically all of the manufacturing plants discharging sewage and trade wastes directly into the river as far up the stream as the garbage disposal plant.

Following a movement of the lake ice early in January, a trip was made out into the lake to the intake cribs. Samples were collected during the entire trip. This trip was made out into the lake on January 10, 1920. Later on March 24, another trip was made out into the lake following the ice as it moved away from the harbor entrance. Samples of ice and water were collected at this time and some instructive data were obtained. On these two trips a harbor tug was used in breaking through the thinner ice near the harbor entrance. A total of 58 samples was collected.

From January 13, to April 1, 1920, raw water samples were collected three times daily at the Division Avenue Pumping Station at 8:00 a.m., 4:00 p.m. and 12:00 p.m., and one sample daily at 8:00 a.m. beginning on January 22, 1920, and continuing until April 1, from the Kirtland Street Pumping Station. In all, 242 samples were collected.

The total number of samples collected and tested during this investigation is between 1000 and 1100.

METHODS OF TESTING SAMPLES

It had always been recognized that whatever the substance was that caused the tastes in the water, the amount thereof present was probably very small.

In the absence of any definite knowledge of this substance, little could be done in the way of specific chemical tests. The addition of chlorine to the water, even in the small amounts used for disinfection, seemed to be able to develop the offensive taste if the substance were present. Hence the use of the "taste or odor test," after addition of chlorine, was decided upon as the test to establish the probable presence or absence of the compound causing the offensive taste.

It was obvious at the beginning of this investigation that some modification of the "taste test" after chlorination of the sample would have to be followed with the sewage and foul river water. Some changes were also found necessary in applying the test as first developed.

During the first month (to February 9, 1920), the method of testing the sewage and river samples was as follows:

A definite amount of chlorine was added to each sample, the quantity of chlorine being sufficient to leave free chlorine in the sample after standing eighteen hours, and to have disappeared in twenty-four hours. The odor was then noted in the cold sample. A portion of the sample was next boiled and the odor noted while hot, and after it had cooled. This treatment after February 9, 1920 was modified, so that a 250-cc. portion of the sample was treated with a moderate excess of chlorine and boiled until no free chlorine could be detected. The odor was then noted after the sample had cooled. It is of interest to state here that a few of the samples gave evidence of the presence of chemical compounds which interfered with our ascertaining whether the water was free from chlorine or not as they gave positive reactions with the starch-iodide test before treatment with chlorine. It also seemed necessary to add enough chlorine to oxidize certain constituents of the water before the odor sought could be detected. Moreover, an excess of chlorine, if not entirely removed, masked the odor as well.

Boiling the sample drove off some of the other odors in the water and brought out more prominently, when present, the characteristic odor being sought. Boiling did not always drive off the excess chlorine or the chlorine compounds formed. An attempt to reproduce the original characteristic odor in samples a month old by a second treatment with chlorine was unsuccessful.

In those samples of water from the lake which it was safe to taste, the procedure was as follows:

Five hundred cubic centimeter portions of each sample were treated with about 0.1 p.p.m. of chlorine. The samples were allowed to stand twenty-four hours and the taste was noted. A portion of the treated sample was then boiled, cooled and again tested by tasting. Beginning February 7, 1920, an additional quantity of chlorine (about 0.5 p.p.m.) was added to the portion of the sample that had already been treated, allowed to stand twenty-four hours, a portion boiled, cooled and the taste noted. They were not tested in the cold because the cold samples, even after standing twenty-four hours, were at times found to contain free chlorine. Some slight modifications of this procedure were at times necessary, when oil or other polluting matter in the lake water samples collected near the harbor entrance required larger quantities of chlorine, longer boiling or both methods of treatment.

In order to learn whether the obnoxious taste could be duplicated, and if a verification of the delicacy of the taste and odor tests used in this work could be obtained, experiments with dilutions of pure phenol (carbolic acid) in distilled water were made. It was possible to detect the taste of 1 part of pure phenol in 25,000 parts of distilled water with a considerable degree of certainty. Dilutions as high as 1 part in 50,000 parts of water could not be detected.

By chlorinating dilutions of pure phenol in water and then removing all excess of chlorine, it was easily possible to detect as little as 1 part of the chlorinated phenol in 5,000,000 parts of water. So similar and characteristic are the odor and taste of these chlorinated products, that once a person has smelled or tasted them, he is not likely ever to forget them.

The offensive odor and taste appearing at times in the public water supply are precisely the same as those produced by chlorinating pure carbolic acid. The extraordinarily small quantities of the chlorinated phenols that are capable of imparting characteristic odor and taste to water explain how easily a relatively small proportion of trade wastes containing phenolic compounds may contaminate vast volumes of the lake water. Whenever the lake water thus polluted passes into the City's intakes the presence of phenolic bodies immediately becomes evident when the water is chlorinated, in the usual course of its purification for public consumption.

DIRECT TEST FOR CARBOLIC ACID

Late last fall there was brought to our attention a delicate test for very small amounts of phenol (carbolic acid) in water. We secured the necessary chemicals to prepare this reagent and have been able to apply it to some of the samples collected early in the year, as well as to use it on some samples recently collected from the Cuyahoga River, and from waste liquors from certain industrial plants. We have found it is a very sensitive test for phenol, but unfortunatly it is also a delicate test for certain other substances. The reagent is a complex mixture of phosphotungstic and phosphomolybdic acids. In a sample of water made strongly alkaline with sodium carbonate this greenish colored reagent produces a blue color in a water containing carbolic acid. Hydrogen sulphide, ferrous iron and cuprous copper will also react with this reagent. Since at least the first two of these compounds are quite likely to be present in polluted waters, the value of the test for this work is doubtful.

RESULTS OBTAINED

It is hardly necessary in this paper to give in detail the results obtained during this systematic survey of river and lake conditions. Over 1000 samples were collected and tested. A summary of the positive characteristic taste or odor results obtained during the investigation is as follows:

SAMPLE TAKEN FROM	TOTAL NUMBER SAMPLES TAKEN	NUMBER POSITIVE
West 58th Street Sewer	217	0
Cuyahoga River at harbor mouth	121	3
Cuyahoga River Fire Stations Nos. 15 and 21	177	9
Water Works intakes	242	121
Lake Erie between harbor mouth and intake	61	25
Cuyahoga River and sewer outfalls into river	221	46
Lake from 1 to 7 miles north of intakes	5	0
Total number of samples	1044	204

DISCUSSION OF RESULTS AND CONCLUSION

The continuous testing of the lake water entering the intakes together with the testing of the river samples, established a relation between the two which was considered especially significant. The results of two lake trips in a tug following ice movements were of special interest, as they indicated the part the ice plays in disseminating polluted matter, and also because of the fact that, on one trip, it was possible to trace the "taste producing material" from the mouth of the Cuyahoga River directly to the area around the intakes of the water works. Coupling this fact with another brought out by the river work, namely, that the same waste material was found to be present in the river water for at least 5 or 6 miles from the harbor entrance, it is possible to present a complete line of evidence, which showed that the polluted water of the Cuyahoga River reached the water works intakes, and that this polluted water contained the material which caused the obnoxious taste. It will also be noted that not a single sample from the West Fifty-eighth Street sewer outfall produced, when treated with chlorine, the characteristic taste.

Of 398 samples collected in the Cuyahoga River and above the mouth of the stream, 55 gave positive tests. Of the 182 samples at the mouth of the river, and between the latter and the intakes, 28 gave positive tests. Of the 242 samples which came through the intakes, 121 or 50 per cent, gave positive characteristic taste. Five samples taken on a single day from one to seven miles north of the intakes gave negative results.

The period covered by the greater number of these tests was during the winter months when the lake contains considerable quantities of floating ice. These ice floes are moved about by the wind. In their movements back and forth in front of the mouth of the river they act like gigantic mixing paddles, stirring and mixing the polluted river water into the lake water. The ice at the mouth of the stream also becomes badly polluted, as our observations showed. As it breaks up or is carried out bodily by floes sweeping by, it may and probably does carry pollution directly to the intakes.

The significance of the positive results obtained in following out the floating ice on a tug on March 24, 1920, is, as previously noted, of great importance, as it links the polluted river water directly with the water which must have found its way into the intakes. Associating this fact with the unquestionably positive results obtained from samples from the Cuyahoga River, and from sewers or polluted creeks discharging into the stream, no doubt remains in the minds of the authors as to the source of the offensive material which at times gets into the public supply.

If the line of positive samples taken from the Cuyahoga River is traced up the stream, it is apparent that no sample containing the offensive odor and taste producing material was obtained above the sewers discharging near the Wheeling and Lake Erie Bridge across the Cuyahoga River. There is, however, an industrial plant further up the stream, which discharges certain of its trade wastes through Burke Creek. The latter empties into the river below the Wheeling and Lake Erie bridge referred to above. This Burke Creek water, when chlorinated, was always shown to be polluted with the material producing the obnoxious taste.

Further down the stream are sewers from another large plant which discharge into the river, and from which positive tests were frequently obtained. It was also true that samples of river water, taken below this latter plant, frequently gave positive tests. Sometimes samples from sewers from plants, which used river water for cooling purposes were obtained, which gave positive tests, but in these cases it seemed more than probable that the river water contained the trade waste before being pumped into the plant using it. Further investigation of a large number of industrial plants along the stream, by inspecting their processes, and by securing and testing samples of sewage or waste before they were discharged from the works into the river, demonstrated that those processes producing wastes, which after chlorination caused the obnoxious taste, were derived from plants engaged in the destructive distillation of coal.

Reference to figure 2 will show some of the products derived from the distillation of coal, and the further distillation of gas liquor and tar. From the gas liquor ammonia and ammonium salts are obtained. This liquor, which is of considerable volume, is concentrated in stills, in which lime is used to separate the ammonium compounds. The concentrate from such stills is wasted. We have never failed, with but one exception, in obtaining the characteristic "carbolic taste and odor" from chlorine treated samples of this waste. Crude carbolic acid is a by-product found in fractioning the tar into light, middle and heavy oils. Small amounts of phenolic compounds are doubtless present at all times in gas liquor, and hence may be present in the concentrate from ammonia stills. At one of the coke oven plants investigated, it was admitted that the waste liquor from their ammonia stills amounted to as much as 40,000 gallons daily. The authors understand that the Waste Disposal Committee of the American Gas Association has been bending its efforts toward devising some method for caring for the concentrate from ammonia stills. It is our understanding that not only the condensed aqueous vapor from the tar main is sent to the ammonia stills but also any scrubbing water used in cleansing the gas. We examined a sample of liquor concentrate from ammonia stills, which came from a gas plant in one of the New England States. This sample reacted to all of our tests in the same manner as those samples taken by us from the by-product coke oven plants in the valley of the Cuyahoga River.

According to Thorpe[4] gas liquors always contain phenols, and in fact smell more or less strongly of them. This authority also states that gas liquors contain from 0.1 gram to 0.35 gram of phenol per 100 grams (0.1 to 0.35 per cent) of gas liquor. He further states that the waste liquors and lime sludges from ammonia stills always contain phenols, and that, on account of their offensive character, great difficulty in disposing of them is frequently encountered.

As a result of this investigation, the authors conclude that the cause of the obnoxious taste and odor, which at times occur in the

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[4] Thorpe's Dictionary of Applied Chemistry, p. 144.

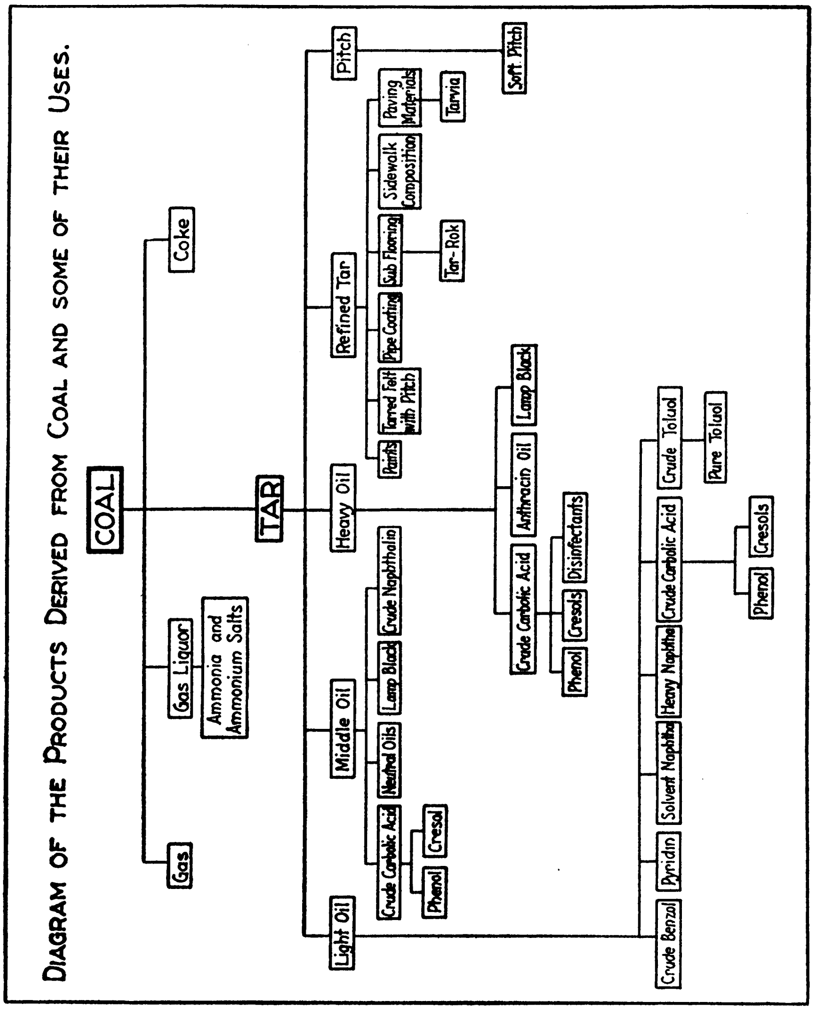
DIAGRAM OF THE PRODUCTS DERIVED FROM COAL AND SOME OF THEIR USES.
COAL
Gas
Gas Liquor
Ammonia and Ammonium Salts
Coke
TAR
Light Oil
Middle Oil
Heavy Oil
Refined Tar
Pitch
Crude Carbolic Acid
Phenol
Cresol
Neutral Oils
Lamp Black
Crude Napthalin
Paints
Tarred Felt with Pitch
Pipe Coating
Sub Flooring
Tar-Rok
Sidewalk Composition
Paving Materials
Tarvia
Soft Pitch
Crude Carbolic Acid
Phenol
Cresols
Disinfectants
Anthracin Oil
Lamp Black
Crude Benzol
Pyridin
Solvent Naphtha
Heavy Naphtha
Crude Carbolic Acid
Phenol
Cresols
Crude Toluol
Pure Toluol

FIG. 2

public water supply, are due to trade wastes from the plants on the Cuyahoga River which are operating by-product coke ovens. The waste liquors and sludges from these plants, derived from the distillation of gas liquor for ammonia and ammonium salts, find their way through sewers and creeks leading into the river and are finally discharged into the lake. This polluted lake water moved about by the winds and ice finds its way into the intakes of the water works. When this water polluted with this waste is chlorinated, in the regular course of purification of the City's supply, a portion of the chlorine unites with the phenol and allied organic compounds, forming substitution and addition products, which are foul smelling and tasting. The original polluting material is in solution and cannot be removed by filtration.

The remedy for this trouble obviously is to prevent the discharge of the offensive trade wastes into the lake water. It is primarily a problem of trade wastes disposal and not water purification.